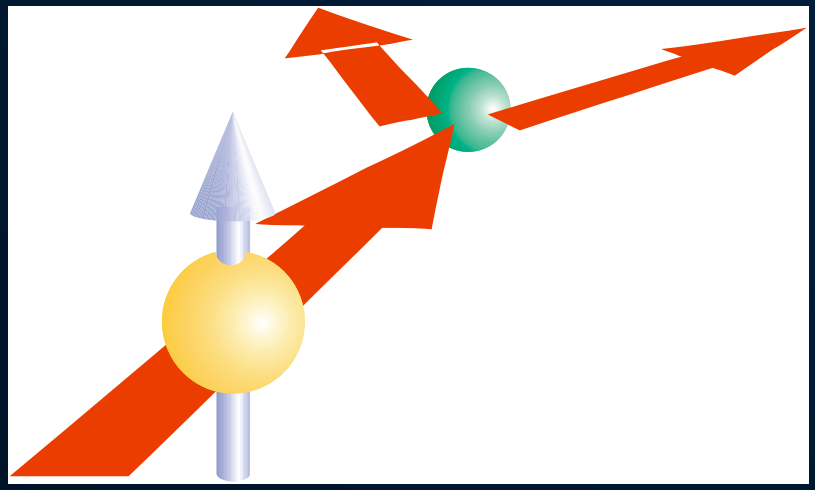
Transverse Single-Spin asymmetries for π+ and π- production from pp collisions at $\sqrt{S_{NN}}$= 200 GeV

- Introduction
- Measurements, Kinematic variables
- Corrections and checks
- Preliminary Physics results
- Conclusion and Prospects

F.VIDEBAEK

Introduction

Left Right



$A_n = (\sigma^+ - \sigma^-) / (\sigma^+ + \sigma^-)$

Where the spin cross section is determined with the spin direction defined by $k_b \times k_{pi}$

- Early (naive) QCD predicted this effect to be small.
- Non-zero Single Transverse Spin Asymmetry (SSA/ A_n) requires Spin Flip Amplitude and phase difference in intrinsic states.
- Such studies may clarify properties of transverse quark structure of the nucleon.

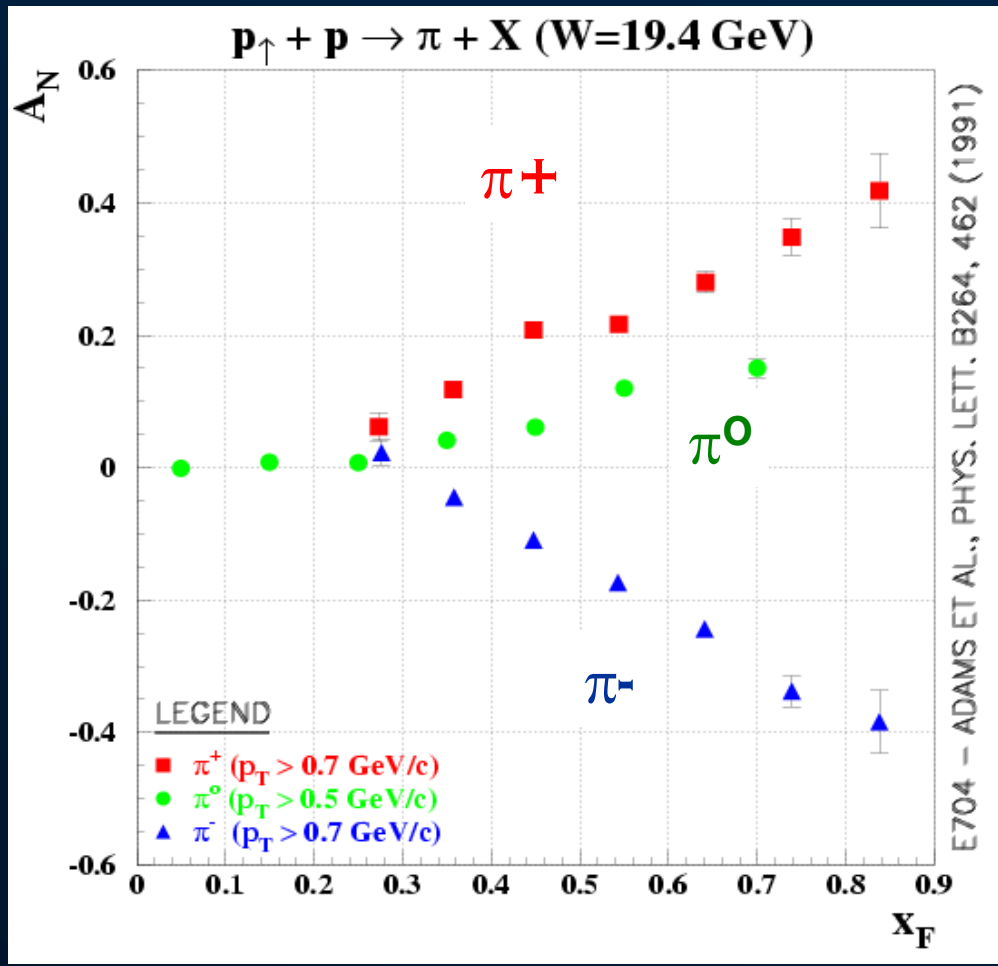
Background

Low energy data (FNAL E704) show clear differences between π^{+-} and π^0.

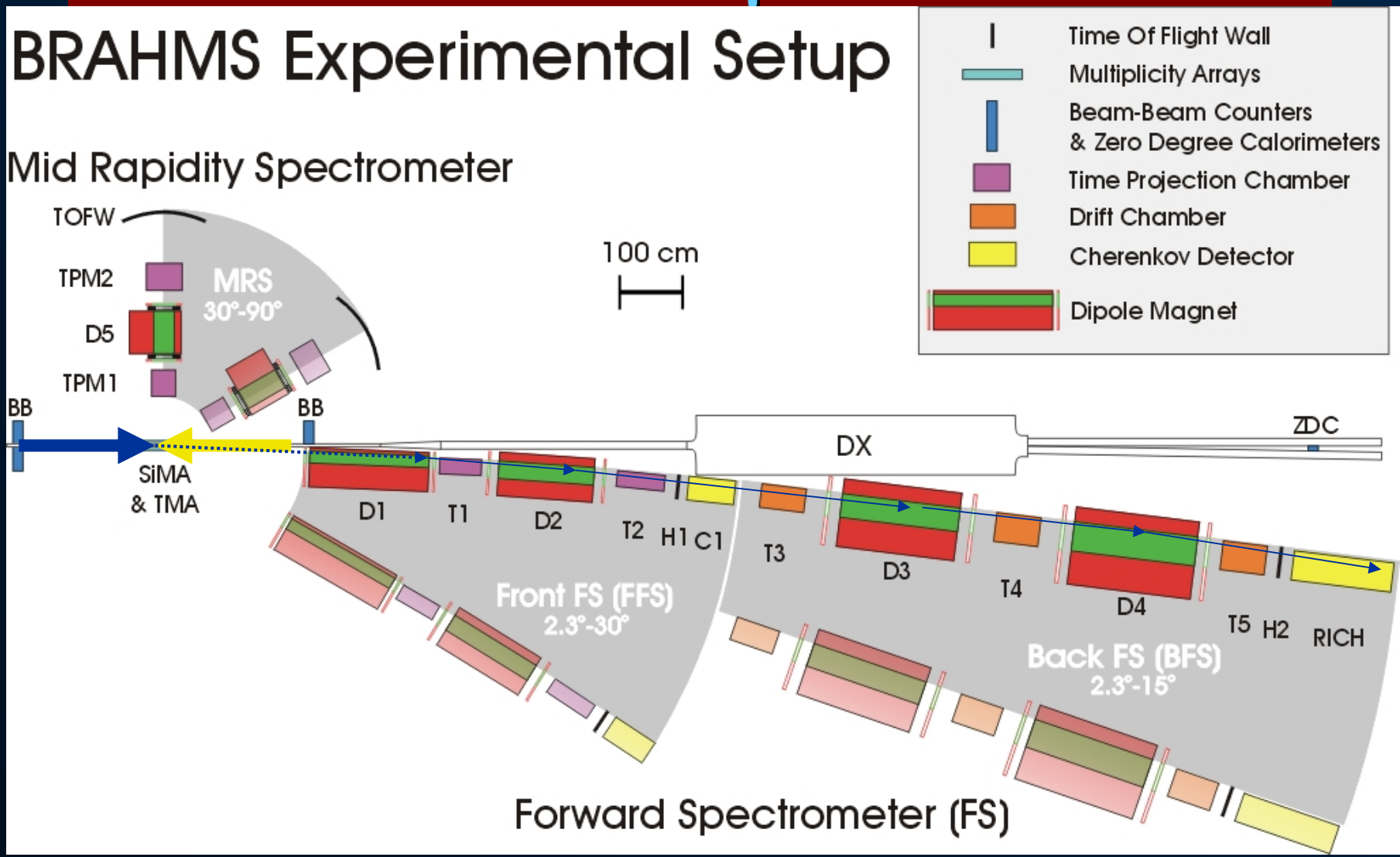
D.L.Adams (E704) Phys.Lett B264,462(1991);

Phys.Rev. D53, 4747 (1996).

Recent STAR results on π^0 also shows a significant SSA/ $\mathbf{A_n}$ at RHIC energies.



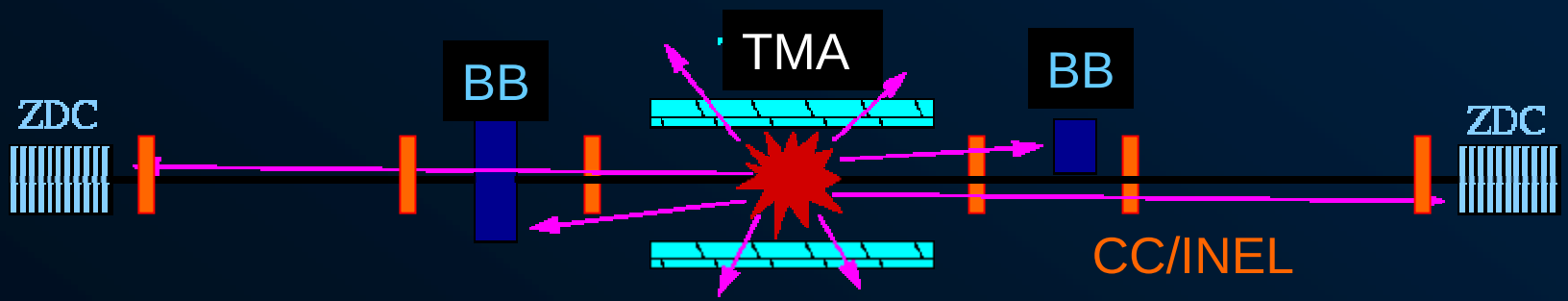
The BRAHMS Spectrometer



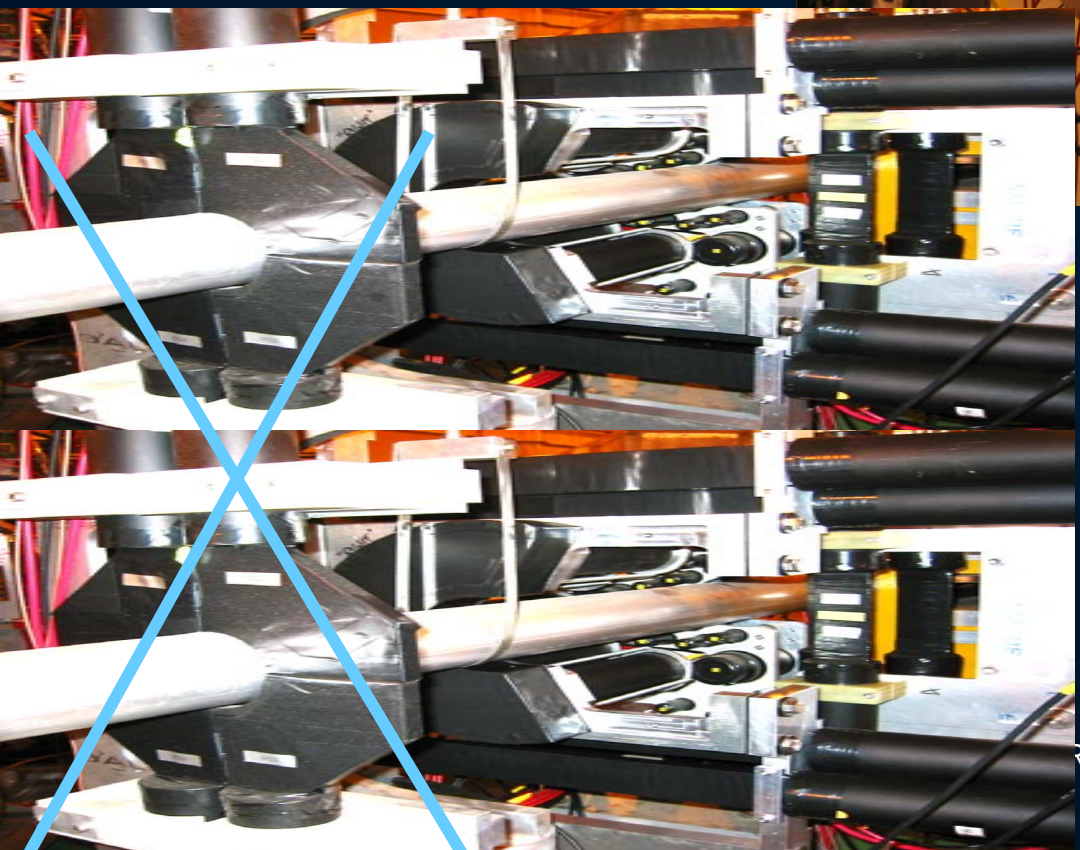
Event characterization

Global Detectors in use for luminosity measures, and inelastic pp cross section

Triggers are defined with the CC,Inel ZDC and BB; p+p collisions were triggered with the INEL/CC detectors.



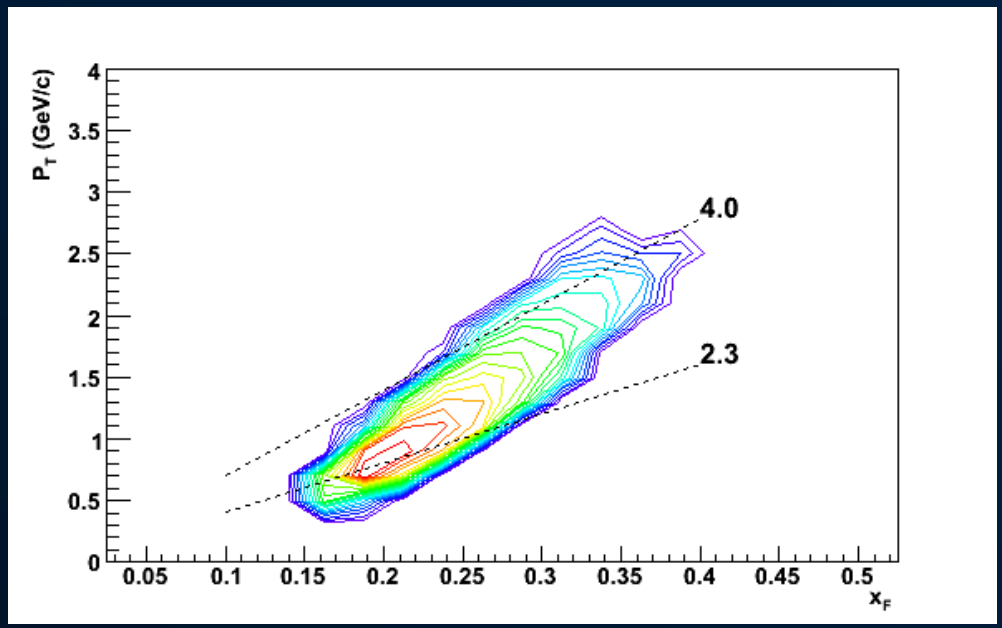
New Min-Bias Counter for pp



- "CC" Counter – Cherenkov Counter
- Installed for pp05
- Covers ~70% of pp inelastic cross-section
- Vertex resolution $\sigma \sim 2$cm

Kinematic Variables

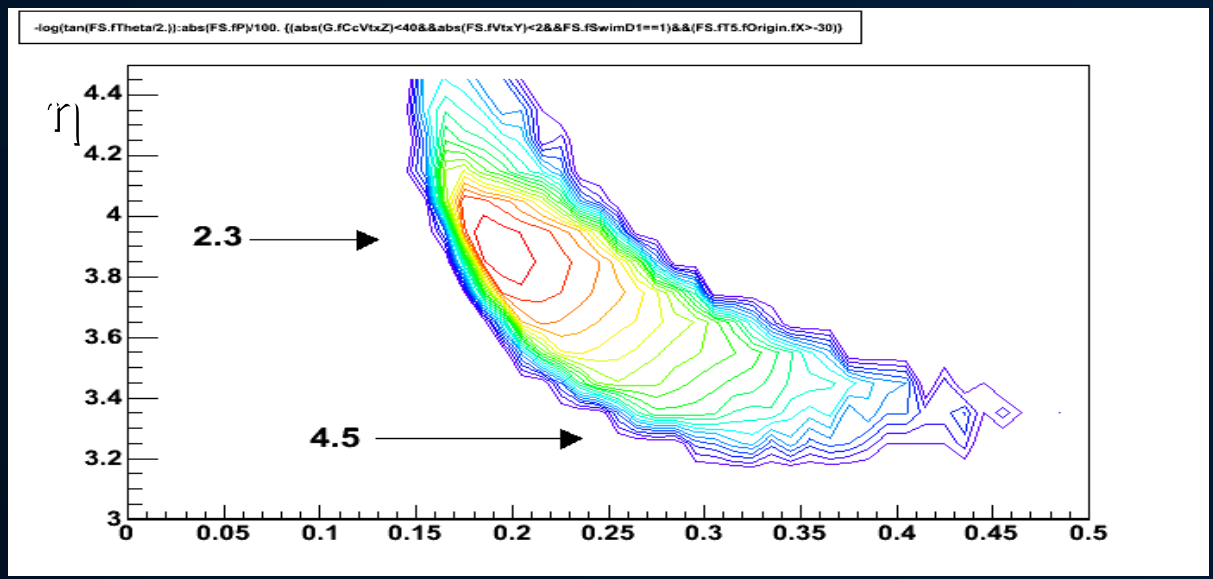
- The kinematic variables of interest are Feynman x (x_F) and p_T.
- Shown is the BRAHMS acceptance for the data taken at θ = 2.3 deg and the maximum field setting (7.2 Tm).



Note the correlation between x_F and P_T as characteristic for a fixed angle spectrometer. The momentum resolution is $\delta p/p \sim 1\%$ at 22 GeV/c.

BRAHMS acceptance

- The acceptance is not *straight* in angle or η. Illustrated in this plot. Thus care should be taken when comparing to both other experiments (STAR) and to theory.



Determination of raw asymmetries.

Asymmetries are determined from $A_n = \varepsilon / P$

The polarization P of the beam was ~42% in the RHIC Run-4 (Blue beam)

With $\varepsilon = (N^+ - N^-) / (N^+ + N^+)$ where the yield of pions in a given kinematic bin with the beam spin direction is N^+ (up) and N^- (down).

For non-uniform bunch intensities

$\varepsilon = (N^+ / L^+ - N^- / L^-) / (N^+ / L^+ + N^- / L^-)$

$= (N^+ - L*N^-) / (N^+ + L*N^-)$ where $L = L^+ / L^-$

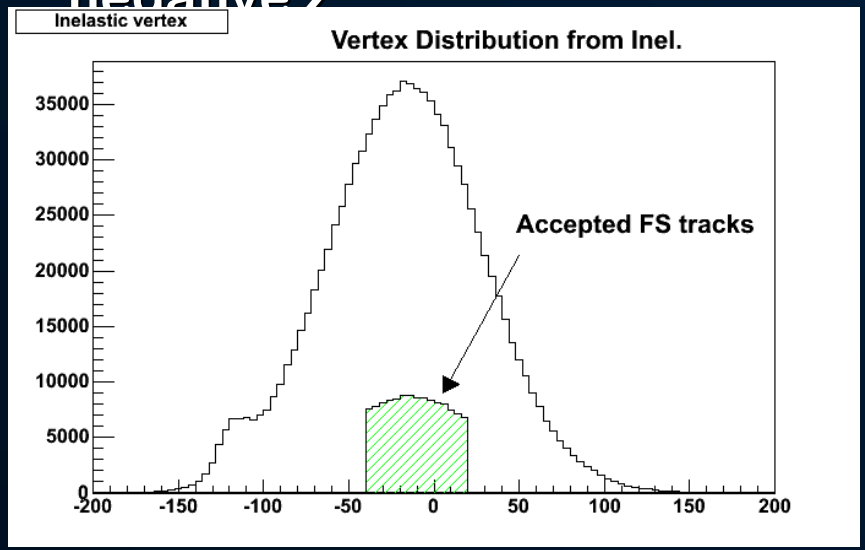
Since the up and down spin patterns alternate most time-dependent systematic errors are small. The main issue is determination of the L^+ and L^-.

Event Selection Criteria

- Clean track through spectrometer and in time with the RHIC 108 nsec clock.
- Momentum determined from 3 measurements.
- -40< Z_Vertex <30 (Vertex from collision) determined from global detectors (INL, BB, ZDC)
- Track points to collision vertex (in Z and Y)
- Good Bunches Only (selected per store)
- Select pions using RICH for particle identification.

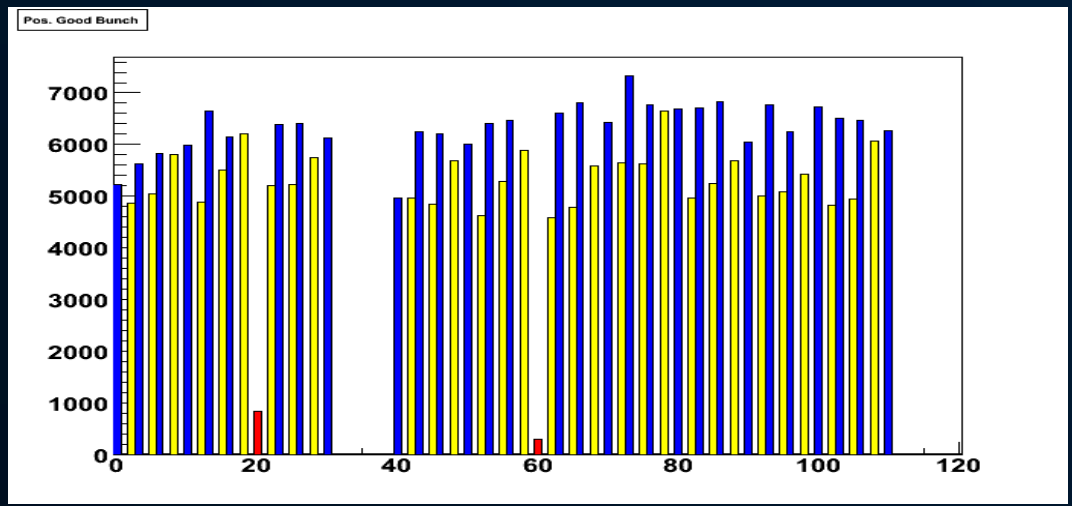
Vertex determination

- Vertex Calculated from timing measurements in sets of counters INEL position on each side of IP covering roughly $2 < |\eta| < 5.2$.
- Z-resolution is ~ 10 cm in Run-4
- The spectrometer accepts track weighted towards negative Z



Bunch Pattern Selection

- Bad bunches with different intensity outside norm is rejected.
- L+/L- ~ 1.05-1.15 typical factors
- Current run-5 have more systematic check with varying patterns.

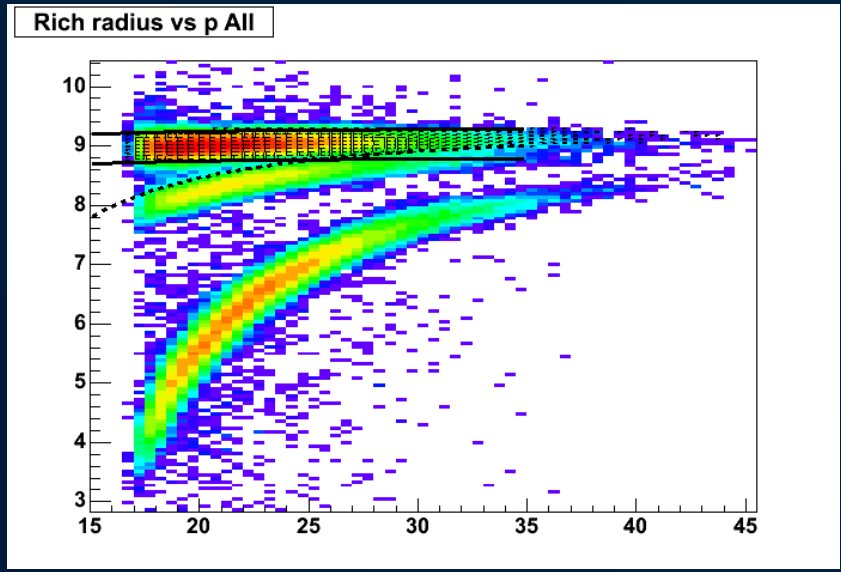


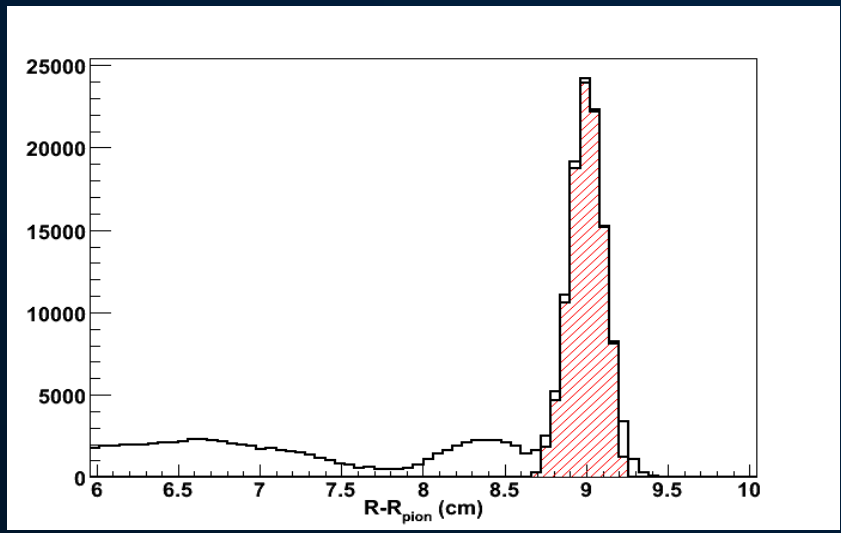
PID using RICH

Mass determined from momentum and Radius measured in a Ring Imaging Cherenkov Counter.

The pion identification is clean up to 35 GeV.

Measured radius vs. calculated showing the selected pions





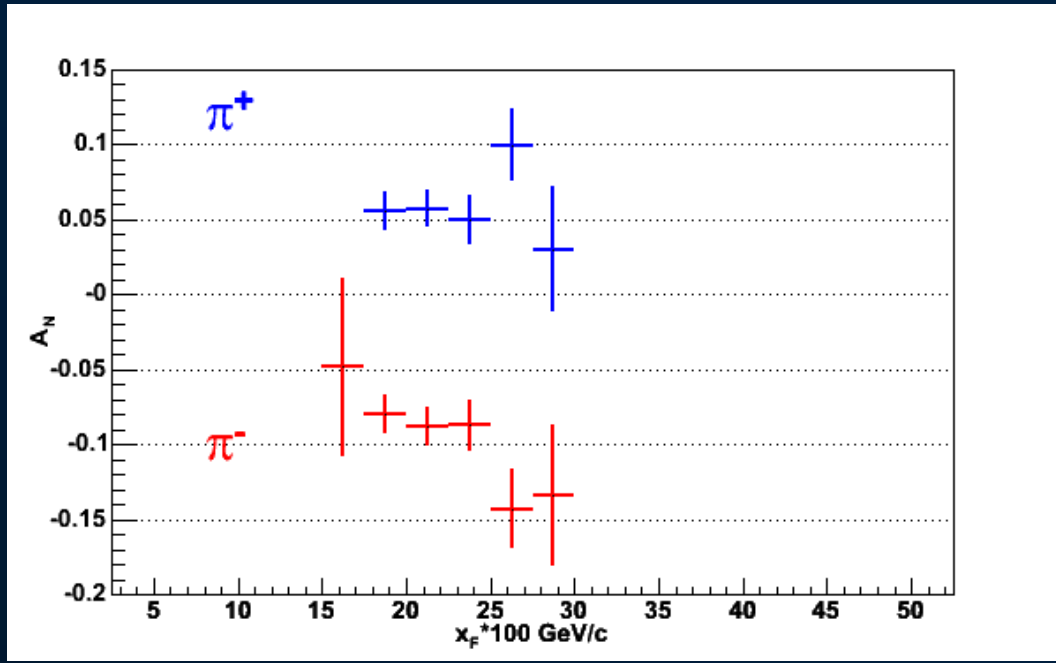
Yields that can be used for analysis

	positive	negative
pion	219K	216K
kaon	46K	26K
proton	165K	17K

Integrated yields of π,K and proton in x_F range 0.15-0.35

Data of A_N for π^+ and π^-

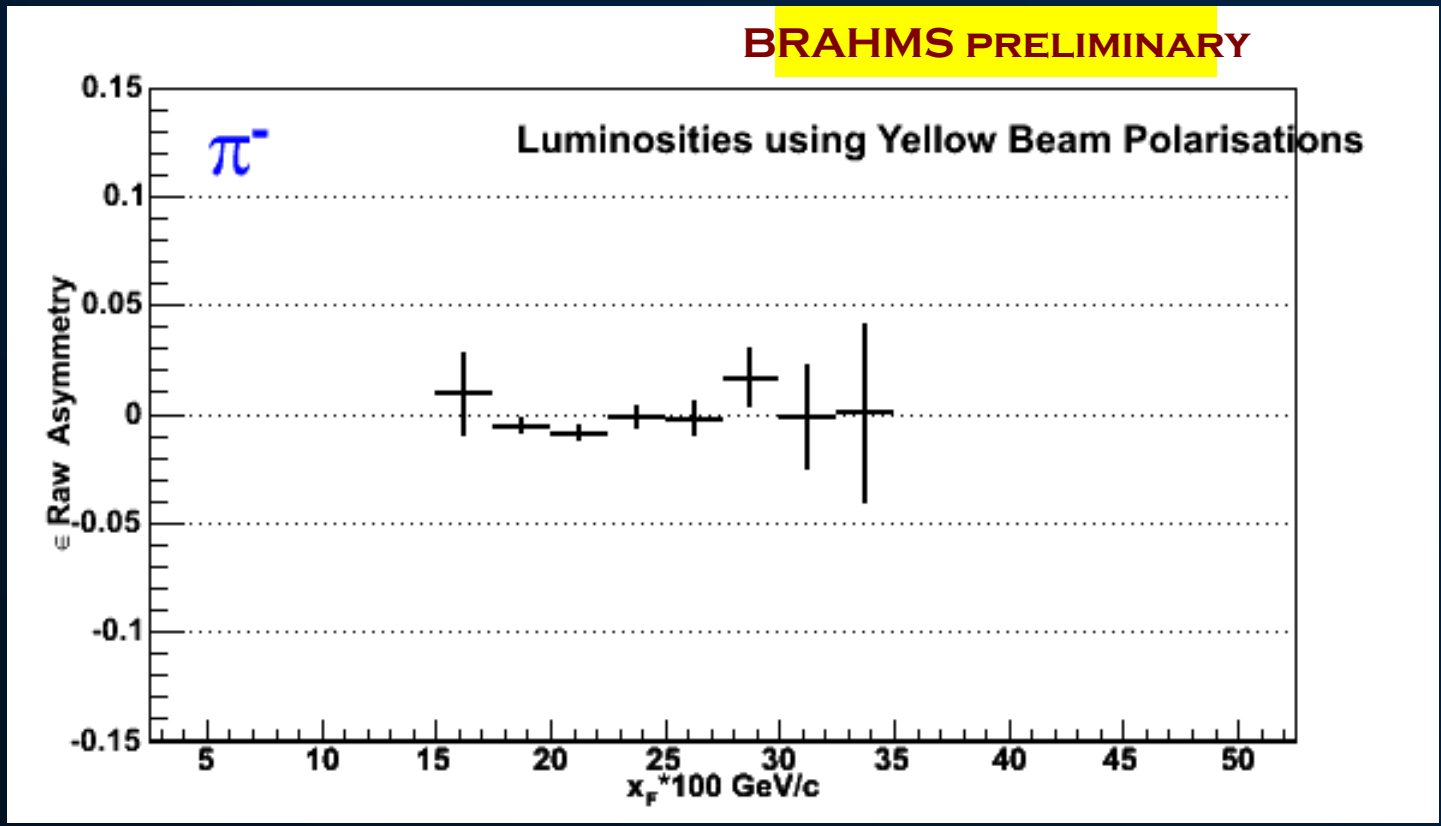
Polarization was ~42% for π^+ measurements and ~38% for π^-. Systematic scale error on P ~ 20-30%. Will improve final final analysis of CNI and Gas Jet data.



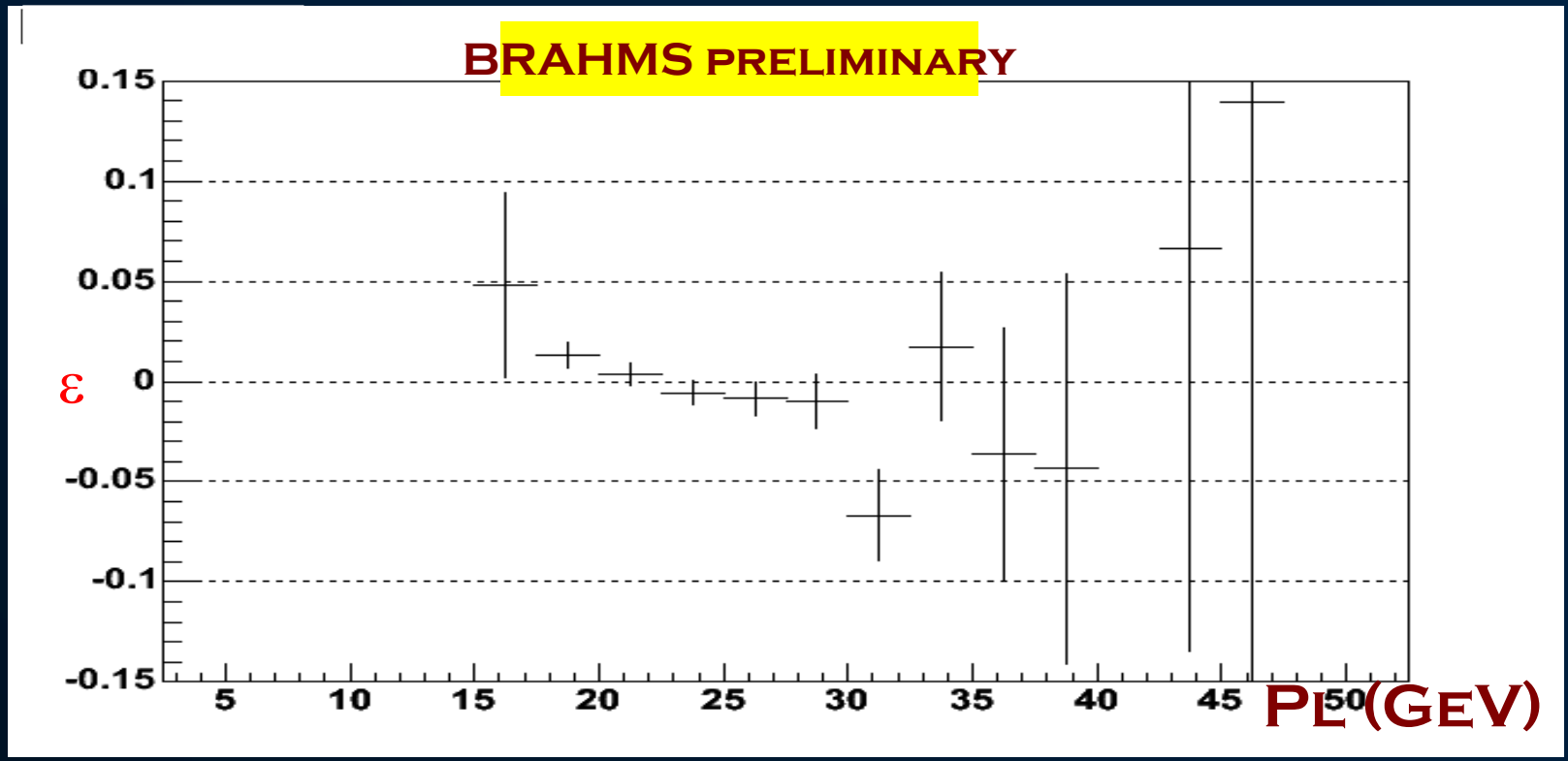
A_N = +0.05 +- 0.005 +- [0.015] in $0.17 < x_F < 0.32$

A_N = -0.08 +- 0.005 +- [0.02] in $0.17 < x_F < 0.32$

π^- and π^+ with yellow Polarization pattern.

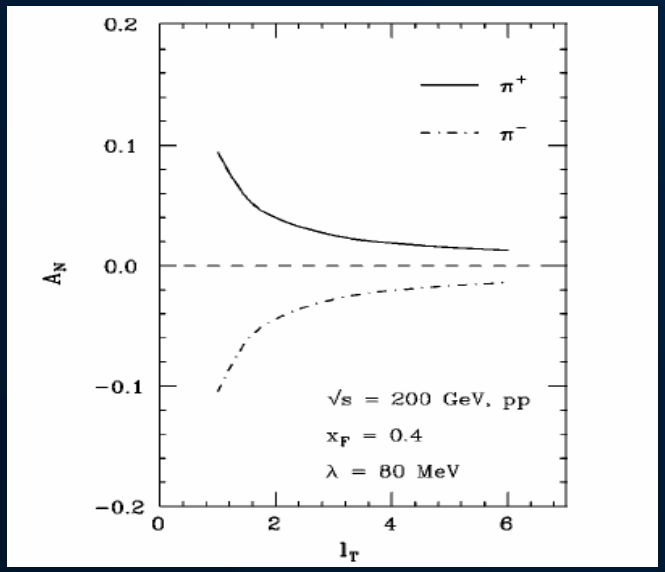


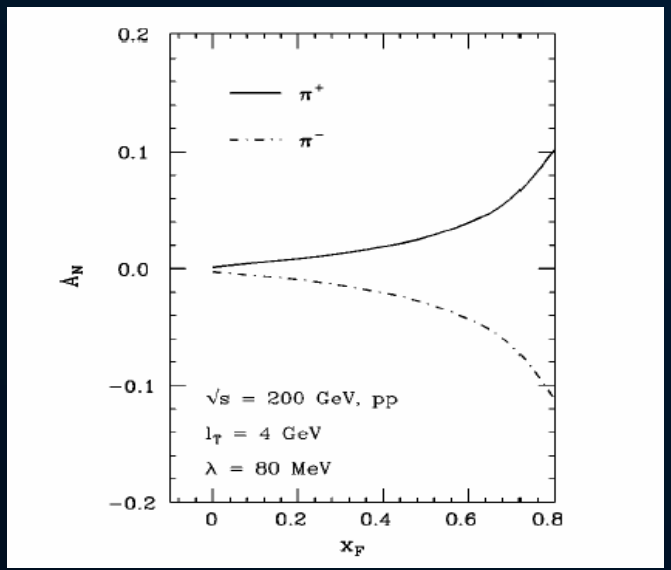
This corresponds to negative x_F, and is consistent as expected.

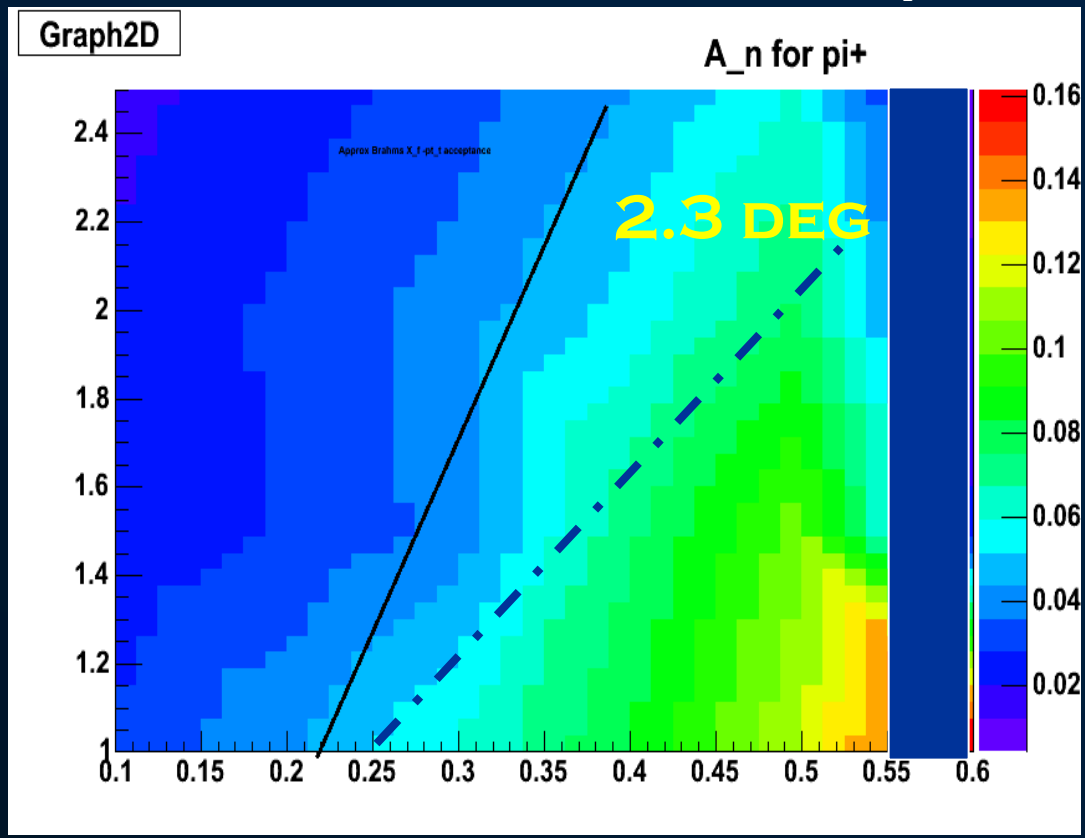


The proton An is also consistent with 0.

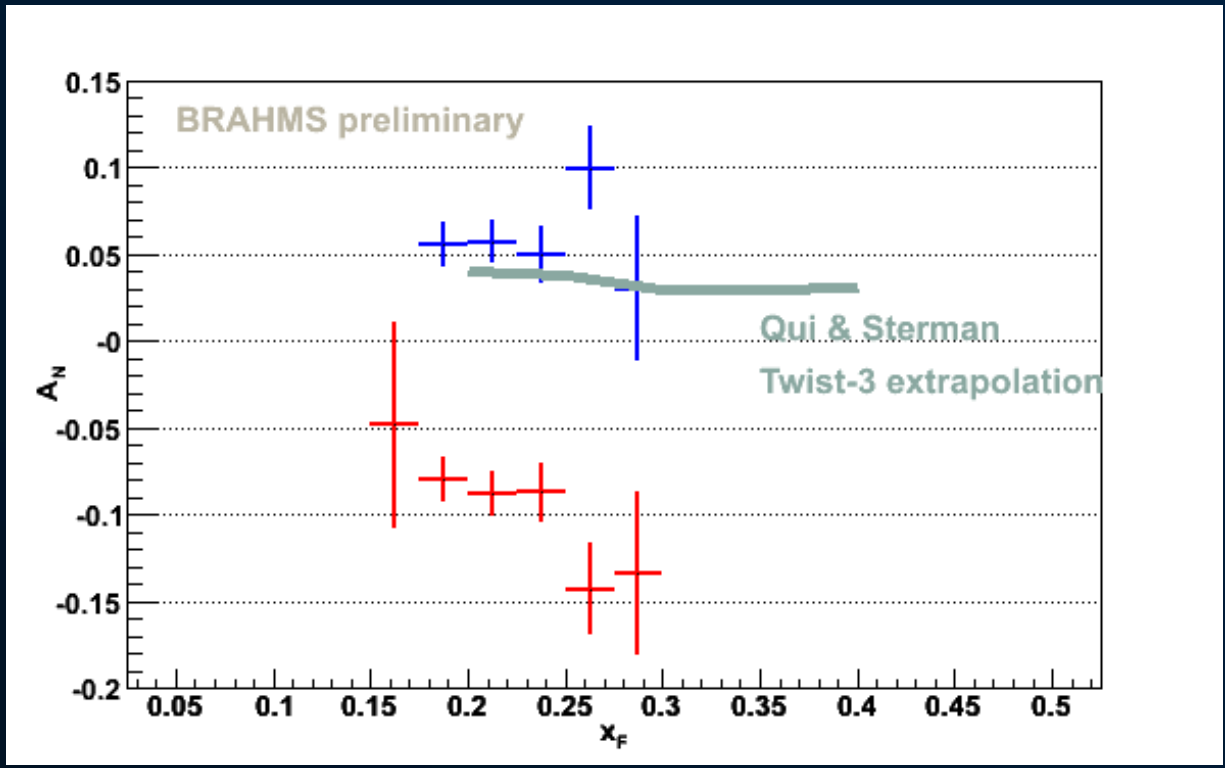
Twist 3 (initial state) calculations by J.Qiu and G.Sterman, Phys.ReV.D59,014004(98) Extrapolated to lower P_T



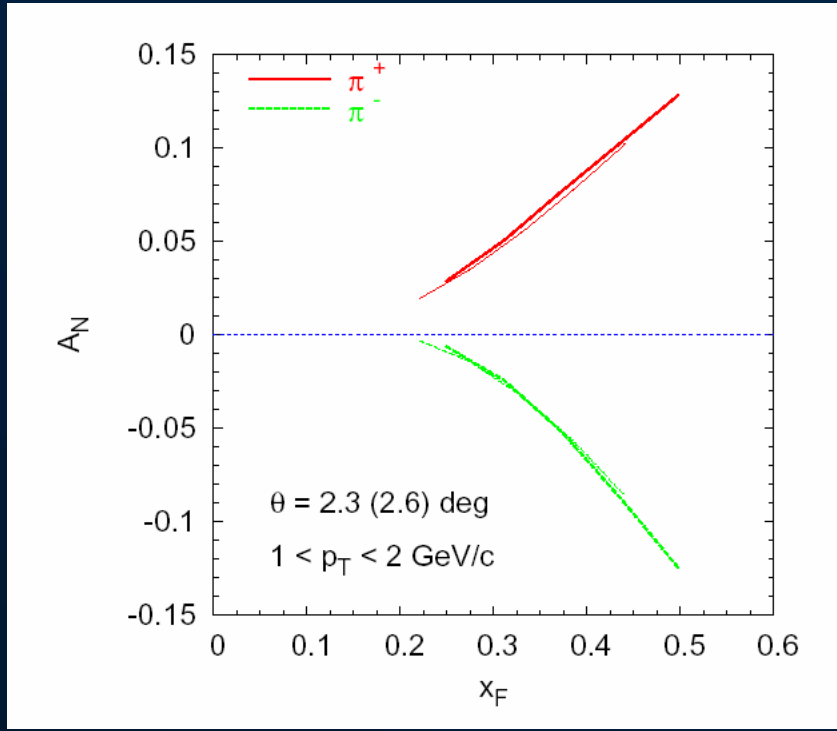




Comparison to data within acceptance.

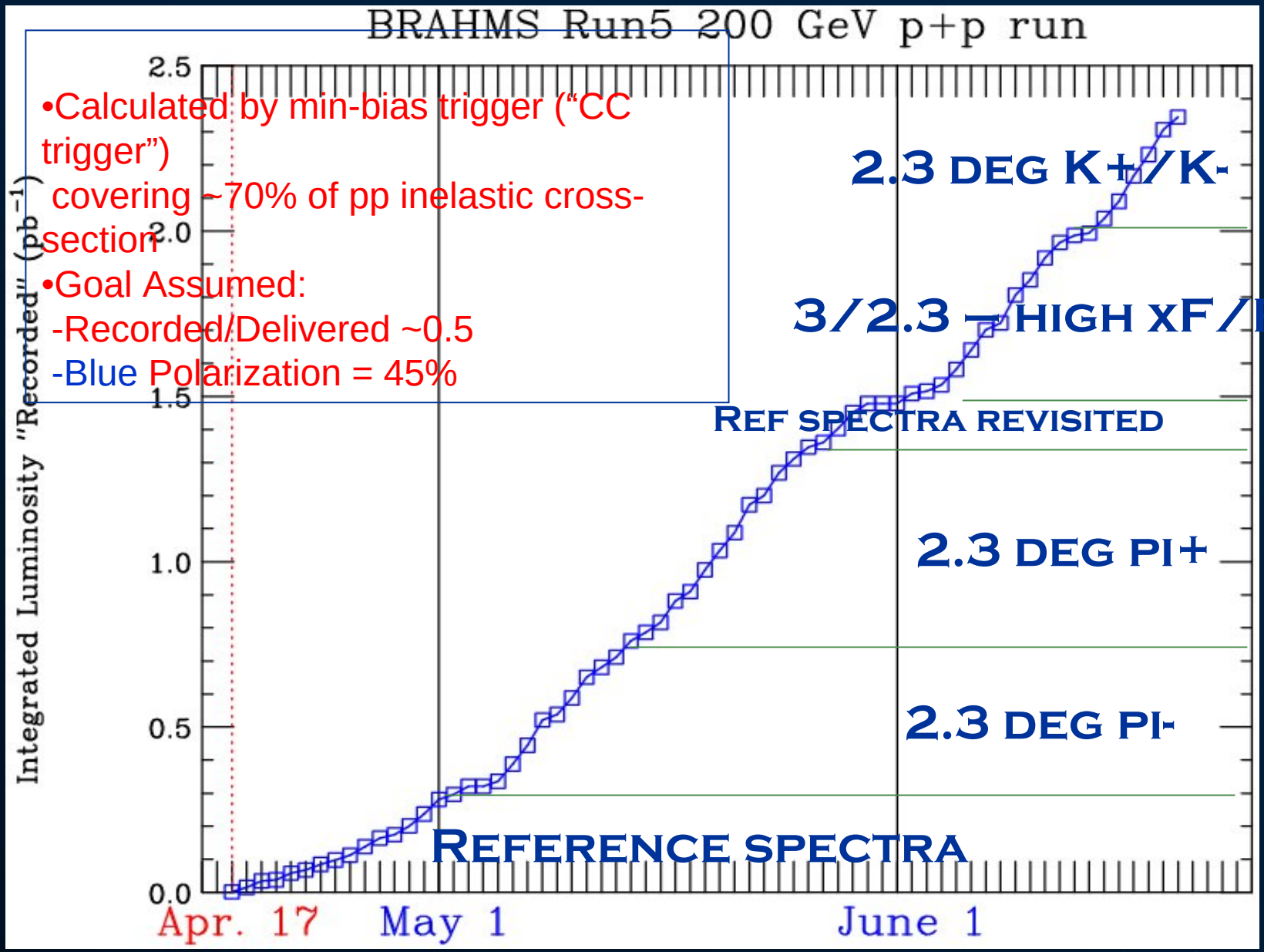


SSA calculations by U.Alesio & F.Murgia PRD70,074009(04); hep-ph/0412317 & private comm.
pQCD approach, including Sivers functions determined from the E704 data.
Asymmetry for pi+,pi-.
Data indicates the opposite trend.



Current RHIC Run

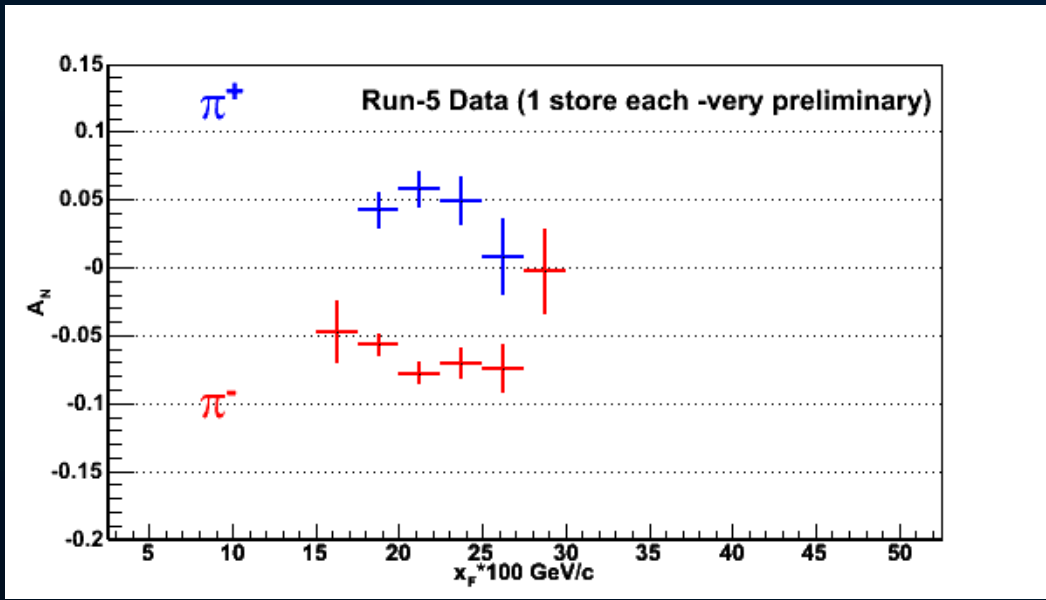
- RHIC Run-5 is just underway.
  - Increased luminosity
  - Polarization ~45-55%
  - New vertex detector with σ_z ~ 2 cm.
  - Additional bunch luminosity measures.


BRAHMS Run5 200 GeV p+p run
•Calculated by min-bias trigger ("CC trigger")
covering ~70% of pp inelastic cross-section
•Goal Assumed:
-Recorded/Delivered ~0.5
-Blue Polarization = 45%
Integrated Luminosity "Recorded" (pb⁻¹)
2.5
2.0
1.5
1.0
0.5
0.0
Apr. 17
May 1
June 1
2.3 DEG K+/K-
3/2.3 – HIGH xF/PT
REF SPECTRA REVISITED
2.3 DEG PI+
2.3 DEG PI-
REFERENCE SPECTRA

3/2.3

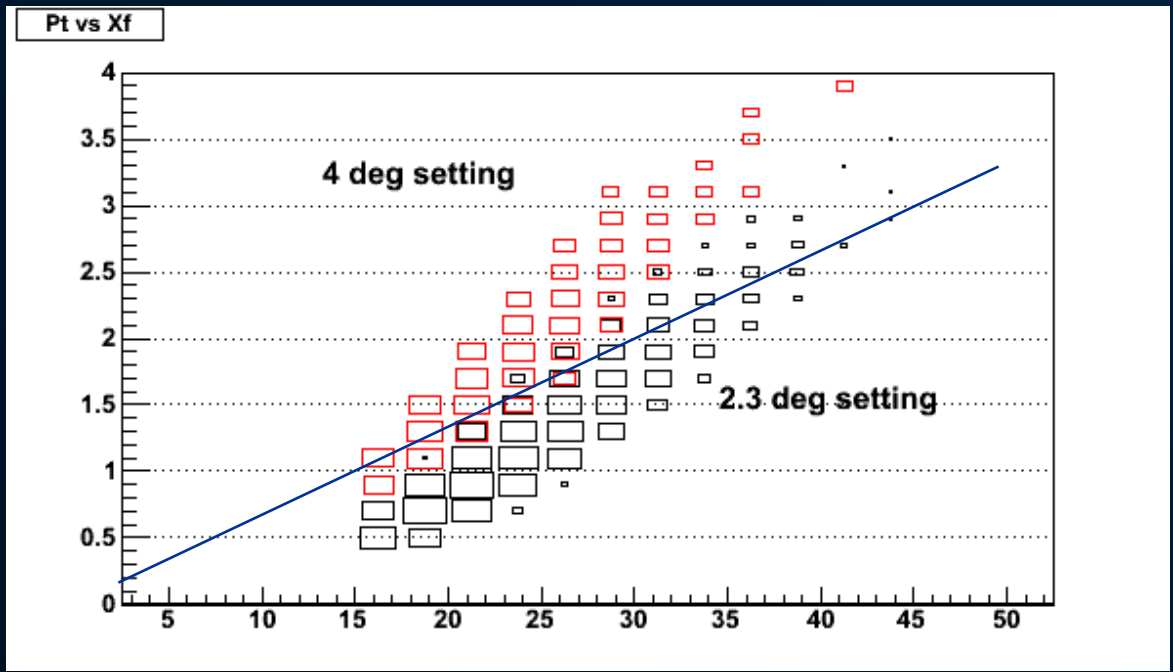
Preliminary Run-5 Data

- Very preliminary data from Run-5 confirms the run-4 measurements.
- Data from just 1(2) stores. Total statistics ~10-20 times this.



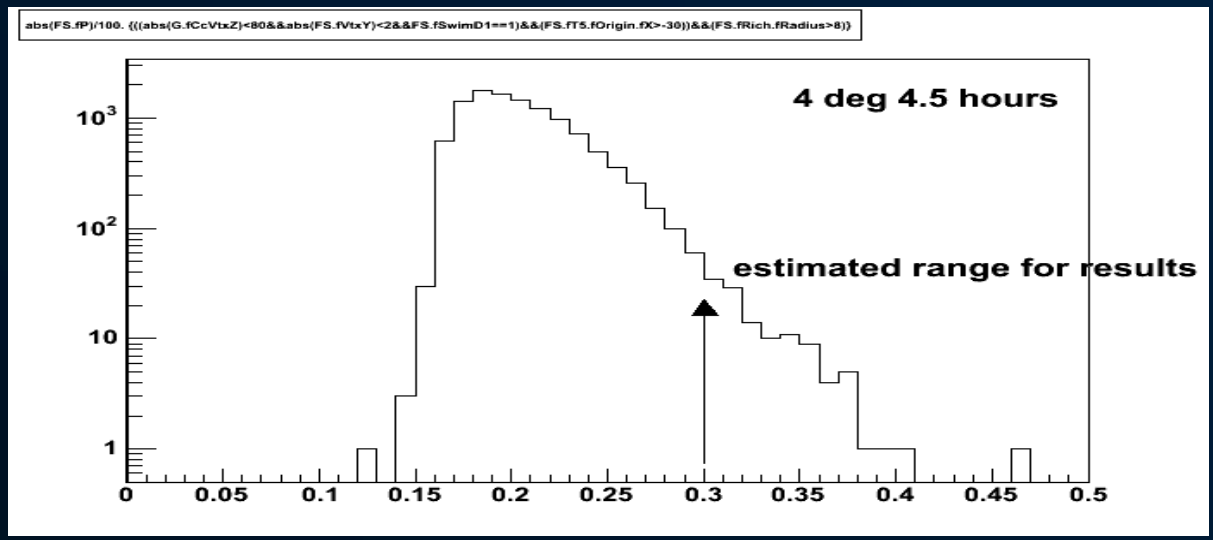
P_T-x_F acceptance

The measurements at 4 deg in addition to 2.3 deg will allow for some P_T coverage.



Expectations for 4 deg

- Statistics obtained for one run



Conclusions

- BRAHMS has obtained the first preliminary result for single spin asymmetries for π^+ and π^- in 200 GeV pp collisions at RHIC in the x_F range of 0.17 to 0.32.
- The A_N value for π^+ and π^- are significantly different with opposite sign, and the $\pi^- < 0$ at ~ 3 sigma level and $\pi^+ > 0$ at ~ 1.5 sigma level
- The sign of A_n is consistent with behavior from lower energy.
- A_n at negative x_F for π^+ and π^- are consistent with 0 (as also found by STAR for π^0)
- The protons are found to have A_N ~0

Summary

- The ongoing Run-5 should enable BRAHMS to extend the measurements to $x_F \sim 0.45$ and to get some information on p_T-dependence at $x_F \sim 0.25$
- RICH operating mode was be changed to get K+/K- out to about 35 GeV/c ($x_F \sim 0.4$)

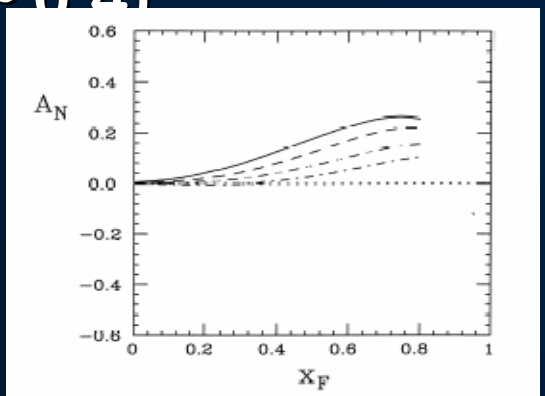


Fig. 4. Predicted single spin asymmetries for the process $p^\uparrow p \to KX$, with the set of kaon FF's BKK1 [19]; kinematical conditions are the same as for the pion case, at $p_T = 1.5$ GeV/c. The solid, dashed, dot-dashed, double dot-dashed curves refer respectively to the K^+, K^-, K^0, K^0_S cases. Results for $\overline{K}^0$ meson are very similar to those for K^- case.

The BRAHMS Collaboration

- 12 institutions-

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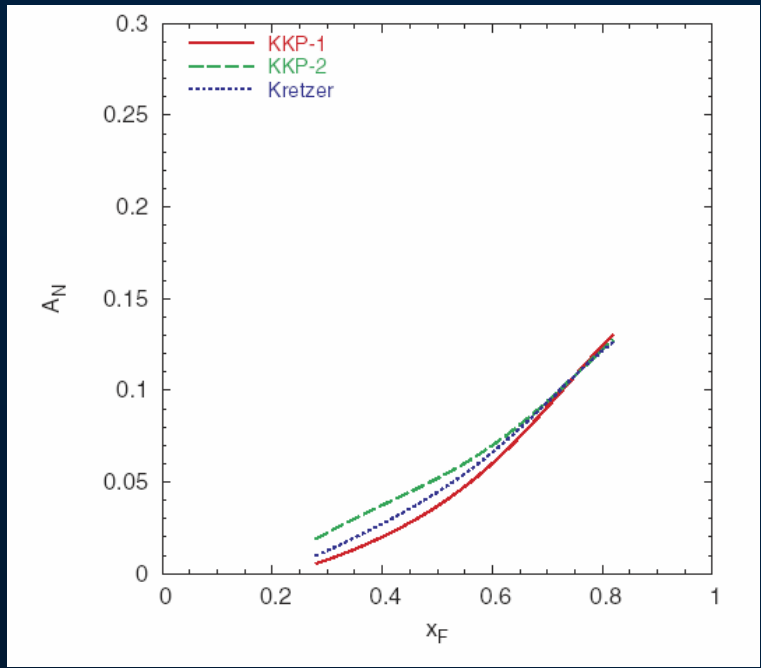
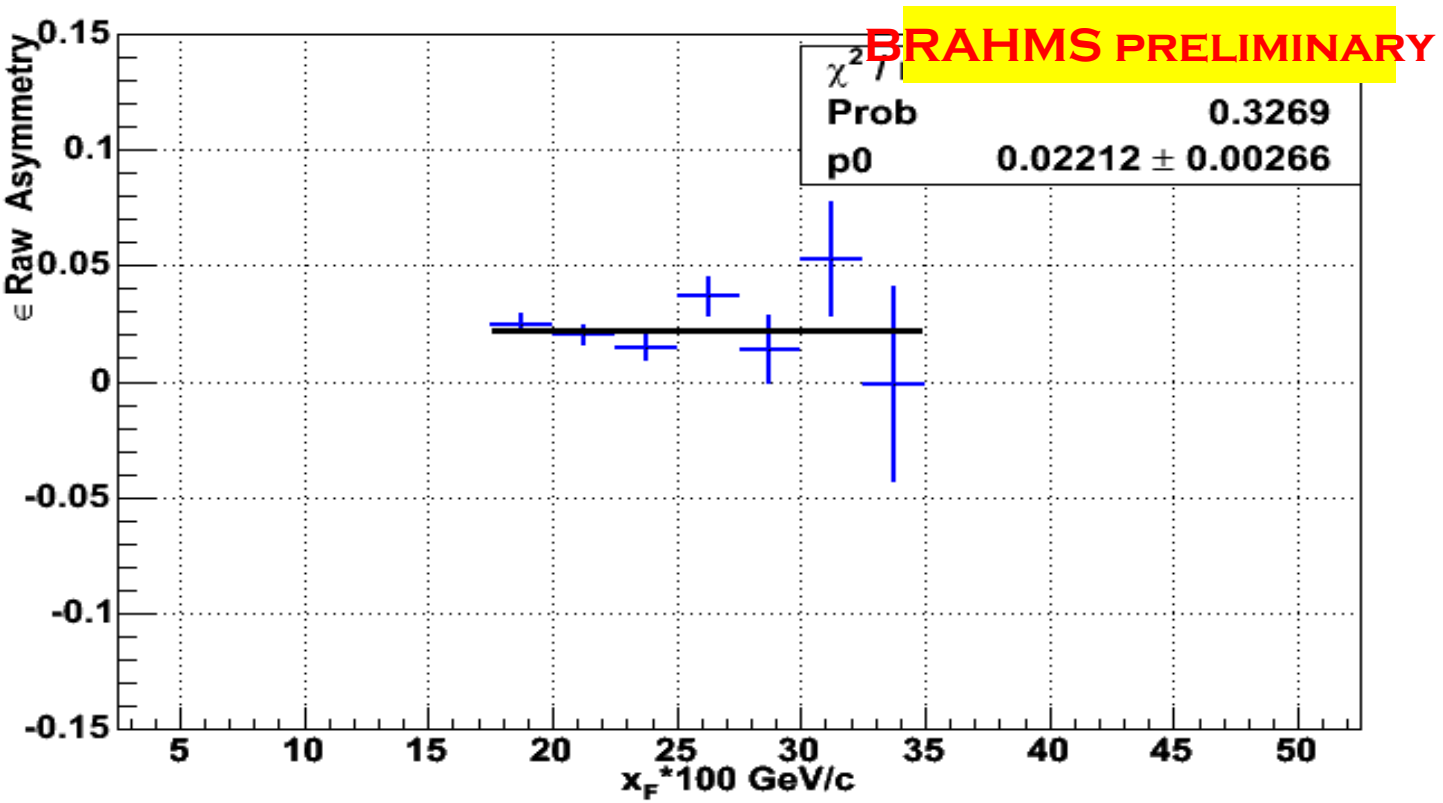
What is sensitivity to fragmentation.

From same paper:
SSA calculations by
U.D'Alesio & F.Murgia
PRD70,074009(04);
Small differences- possibly not distinguishable within our data stat and systematic.



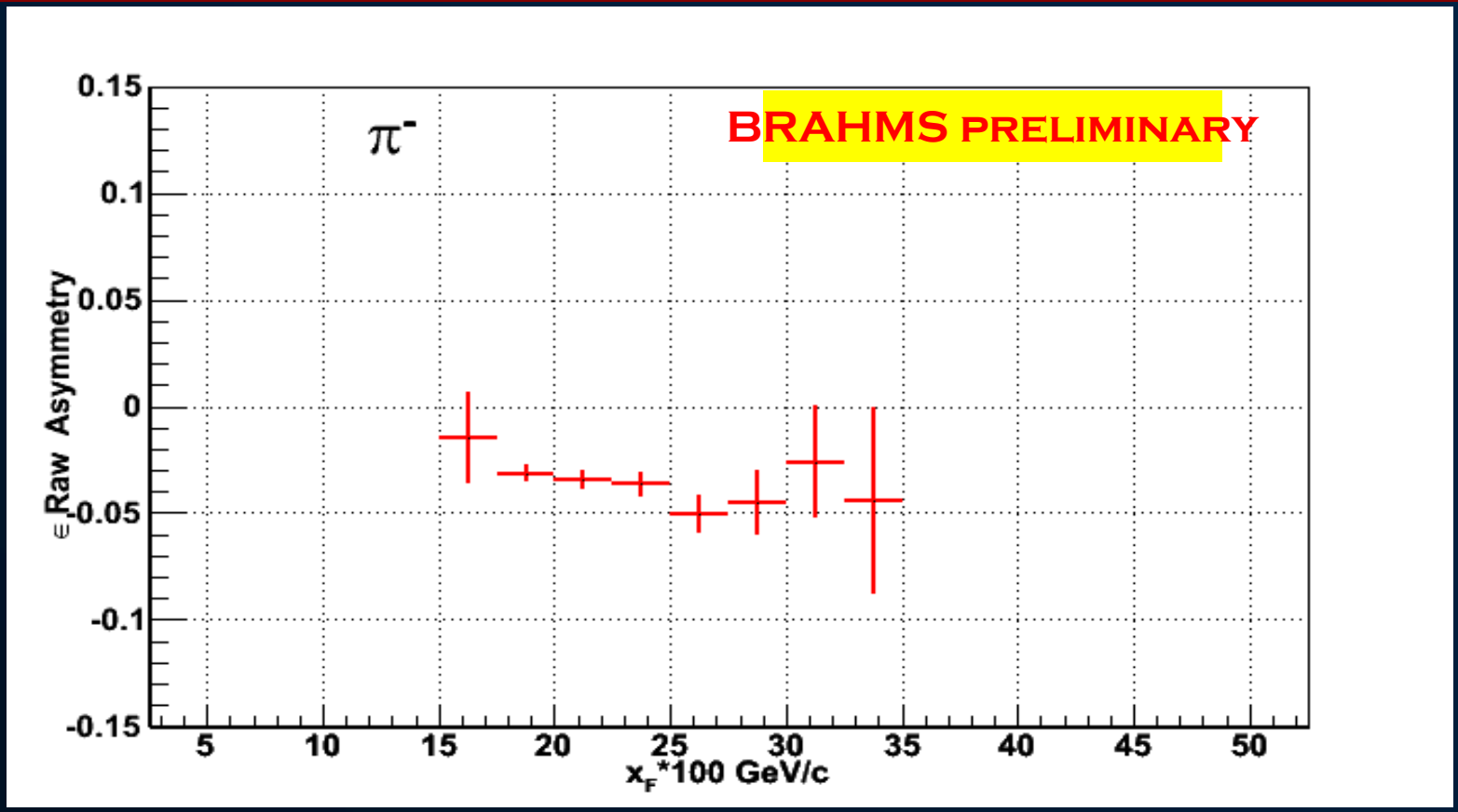
For STAR kinematic acceptance.

$\pi+$ ε vs. $x_F * 100$



$\langle\varepsilon\rangle \sim +0.022 \Rightarrow A_N = +0.05 \pm 0.005 \pm [0.015]$ in $0.17 < x_F < 0.32$

π^- ε vs. $x_F * 100$



$\langle\varepsilon\rangle \sim -0.035 \Rightarrow A_N$ = -0.08 +- 0.005 +- [0.02] in $0.17 < x_F < 0.32$